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MARTIAN ENVIRONMENTAL EFFECTS ON SOLAR CELLS
AND SOLAR CELL COVER GLASSES

Contract No. 952582

TTU Report 3101 - 4th Quarterly
15 July 1970

Prepared by
F. Alton Wade
Principal Investigator

Texas Tech University
Department of Geosciences
Lubbock, Texas 79409

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Abstract

The project includes the subjection of solar cell assemblages to dust storms in wind tunnels where simulated Martian environmental conditions prevail. The electrical performance of the solar cells is determined by tests before and after subjecting the cell assemblages to dust storms. Damage to the cover glasses and cells is assessed by microscopic examinations and measurements. To date all tunnel runs have been completed; eight (8) at ambient temperatures, eight (8) at 245°K, and eight (8) with diurnal temperature range of 233°K-293°K. Electrical performance has been determined on 50% of assemblages following tunnel runs. No detailed damage assessments have been concluded.

Summary

Various investigators have suggested that dust storms do occur in the rarefied atmosphere of Mars. Because the possibility does exist, it is necessary that the effects of such storms on the performance of solar cells be determined prior to a soft landing on Mars. During dust storms fine particulate matter could be deposited on the cells and the cover glasses could be abraded. In either case the efficiency of the solar cells would be reduced. In order to determine how extensive the damage and blanketing effect to the cover glasses might be and the resulting reduction in their efficiency a series of experiments under predicted Martian environmental conditions has been specified.

A wind tunnel of the "race track" type was constructed of plastic and was used in tests at ambient temperatures. A second wind tunnel was constructed in part of plastic and in part of sheet metal. The entire tunnel was insulated with sheets of styrofoam. Provision was made for the introduction and removal of solid CO_2 in order to control the temperature within the tunnel. Eight runs were made in simulated dust storms at a nearly constant temperature of 245°K . Eight runs were made with diurnal variations in temperature which approximated a range from a minimum of 233°K to a maximum of 293°K .

Current-voltage curves were made for each cell assemblage prior to a wind tunnel test and have been or will be following each test. By this procedure the effect upon the electrical performance of each cell assembly can be determined. Cover glasses are then cleaned and performance of solar cells again determined thus evaluating the permanent damage to solar cell cover glasses.

Cell assemblages are tested in groups of four with each subgroup having cover glasses of different materials, namely, quartz, Corning No. 0211 Microsheet, sapphire, and integral.

In all twenty-four tests solar cell assemblages have been coated with a layer of dust which resulted in a critical reduction in the efficiency of the solar cells. Inspections after cleaning the cover glasses reveal permanent damage to most surfaces, mostly pitting. Sapphire cover glasses appear to resist abrasion more than due the other types and exhibit least permanent damage.

Two failures of silver mesh connectors occurred and low temperatures reduced the adhesive characteristics of the cement used to secure the cover glasses.

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Introduction

Most observers of Martian atmospheric phenomena accept the suggestion that the yellow clouds are dust clouds. Because no reasonable alternative suggestions have been offered, we must accept the possibility that dust storms do occur in the Martian atmosphere. The effects of wind driven dust and sand particles on equipment to be landed on the Martian surface must be determined. If such effects are detrimental to the operation of the equipment, changes to eliminate these effects must be incorporated in their design.

At present most items of equipment which are flown in space or landed on an extraterrestrial body receive their power from solar cell assemblages. In space or on the lunar surface there are no dust storms so the problem of their detrimental effect has not existed to date. On Mars the problem may exist and equipment may become inoperative for lack of power following a dust storm.

In order to determine the effect of dust storms on solar cells and solar cell cover glasses a series of tests has been designed in which these objects will be subjected to dust storms at specified wind velocities, temperatures or temperature ranges, in a carbon dioxide atmosphere containing a trace of moisture. These tests will be carried out in wind tunnels designed specifically for them. To assess the results the following tests will be made.

- (i) The total transmission of the solar cell cover glasses before and after subjecting them to dust storms.

- (ii) Microscopy of solar cell cover glasses using phase contrast and polarized light techniques.
- (iii) Current voltage curves will be made before and after exposure to dust storms as is necessary to evaluate the effects upon the electrical performance of the solar cell cover glass combinations.
- (iv) Following (iii) cover glasses will be cleaned and the measurements repeated in order to determine decrease in electrical performance due to permanent damage.

Technical Discussion

Based upon data presented in JPL Document No.606-1, dated July 15, 1968 (1), the Martian environment at or very near the surface is as follows.

Surface pressure - ~10mb

Composition of the atmosphere - >50% CO₂, the remainder probably an inert gas such as argon, plus or minus trace of water vapor.

Temperatures

Maximum at equator - ~305°K

Minimum at equator - ~170°K

Mean amplitude of diurnal variation at equator - ~96°K

Mean polar cap region (estimated)

Winter - ~220°K

Summer - ~265°K

The surface material is believed to resemble olivine basalt or tholeiitic basalt. The surface layer is probably composed of unsorted particulate basalt which ranges in size from a few microns to blocks measuring tens of centimeters in dimensions.

Wind velocities based upon observed motions of yellow clouds may range up to 100 km per hour.

In the design of the tests to which solar cells and solar cell cover glasses will be subjected some exceptions to the above specifications were made.

Pressure. Because of the extreme difficulty in maintaining a pressure of 10 mb and wind velocities of up to 100 km/hr in a wind tunnel, it was agreed to use ambient pressures. Actually this will result in "worst case" phenomena during tests. Corrected wind velocities can be determined mathematically.

Atmosphere. The atmosphere will be 100% carbon dioxide ± a trace of water.

Temperature. One series of tests will be run at ambient temperatures, a second series at 245°K and a third with a diurnal variation from 233°K and 293°K.

Wind Velocities. One series of tests will be conducted with wind velocity at 50 km/hr, and a second at 100 km/hr.

Particulate Matter. The dust particles to be used in the tests were obtained by grinding and sieving olivine basalt which was collected in the Hudson Mountains, Ellsworth Land, Antarctica. The principal constituents are clinopyroxene, plagioclase and olivine. A small amount of glass is present. This differs somewhat from the composition of the fines in the lunar soil obtained by the astronauts of Apollo 11. In the lunar material glass constitutes about 50 percent and ilmenite is a principal constituent (2). These compositional differences should not alter the results of the tests significantly. Wind tunnel tests have shown that movement of particles of less than 60 microns in size will not be initiated by wind velocities of 100 km/hr or less. The presence of slightly larger particles is necessary to initiate movement. These larger particles move by the process of saltation and with every bounce finer particles are knocked into the air stream where they remain in suspension. The fines in the lunar soil material brought to earth by the astronauts in the "bulk box" were composed of approximately 45% in the 125-62.5 micron range and 25% in the less than 62.5 micron range (2). Based upon observations of the generation of dust storms in the wind tunnel using various size particles, it was decided that "worst case" conditions could be obtained using a mixture of particulate matter

composed of 75% in the 125-250 micron range and 25% in the <62.5 micron range. These are weight percentages.

The schedule of tests to which groups of solar cell assemblages have been subjected is shown in Figure 1.

Descriptions of the two wind tunnels in which tests were conducted are in the appendix.

TEMPERATURES																			
AMBIENT				AVERAGE (245°K)								DIURNAL CYCLE (233°K-293°K)							
Days	Vel. km	Atmos. CO ₂	SOLAR CELL PROTECTION								SOLAR CELL PROTECTION								
			Corning #0211 Micro-sheet				Integral Glass Covers				Corning #0211 Micro-sheet				Integral Glass Covers				
			A	B	A	B	A	B	A	B	A	B	A	B	A	B			
1	50	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	100	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	50	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	100	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

A=Expanded silver mesh
 B=JPL bus bar DWG. #10016709-1
 X=Tests in tunnel completed

Figure 1. Schedule of Tests

Discussion of Preliminary Results

As indicated in Table 1, twenty-four sets of cell assemblages have been subjected to dust storms which have been generated in wind tunnels. Each set was composed of four solar cell assemblages which differed in the material of which the cover glasses were made, namely, Corning No. 0211 Microsheet, silica, sapphire and integral. Duplicate runs were made under each set of environmental conditions, the only difference was in the type of connectors in the assemblies. In the first test the connectors were of silver mesh and in the second JPL bus bars (Dwg. #10016709-1) were used.

In tests conducted at ambient temperatures a dust coating accumulated on all solar cell assemblages. The thickness of the coatings varied considerably. In general it appears that the coatings were thicker after exposure to 24 hours of dust storms than after exposure for 72 hours. It is suspected that the thick first coatings were reduced by subsequent abrasion.

The dust coatings adhered to the cover glasses and to all parts of the assemblies with such tenacity that they were removed with great difficulty. After much experimentation the following technique was adopted.

- (1) an assemblage was placed in a jet stream of compressed air. The velocity was increased slowly until no apparent reduction in coating material was noted. This process resulted in the removal of all but a thin coating of dust on the cover glasses.

- (2) assemblages were sprayed then with "Windex" and each cover glass was cleaned while being

observed under the lenses of a binocular microscope. "Q-tips" were used in this operation to remove the dust and to polish the cover glasses.

In tests conducted at low temperatures and in the diurnal range the coatings in general were thicker than those produced at ambient temperatures. They were, however, more cake-like and, even during the most careful handling, portions of these cakes would drop off exposing nearly clean portions of the cover glasses to which they had adhered.

In two cases silver mesh type connectors failed; one during a dust storm and the second during cleaning operations.

The cement used to attach the cover glasses loses its adhesive property to some extent when subjected to low temperatures. Two cover glasses became detached during a 72-hour run under diurnal temperature range conditions. Two cover glasses on an assemblage that had been subjected to a temperature of 245°K became detached during cleaning in the jet air stream.

No detailed analysis of the reduction in efficiency of the solar cells due to dust accumulation has been completed. It would appear, however, that a reduction in efficiency to 20% is a reasonable estimate. Cleaning of the cover glasses restores the efficiency of the assemblages to approximately 95% of their original values.

References

1. Mars Scientific Model. JPL Document No. 606-1.
July 15, 1968. Prepared by members of the Lunar
and Planetary section.
2. Preliminary Examination of Lunar Samples from
Apollo 11, 1969. Science, Vol. 165, p. 1219.
Prepared by the Lunar Sample Preliminary Examination
Team.

Appendix

Description of Wind Tunnel No. 1.

The wind tunnel for test experiments at ambient temperatures and preliminary tests is constructed mainly of quarter inch plexiglass. It is essentially a closed system shaped like a race track (Figure 2). The 'atmosphere' is circulated with a squirrel cage blower which is driven by an electric motor. Wind velocities in the straight-away sections of the race track where the tests are performed are controlled by varying the cross section.

Three pairs of straight-away sections are available. With one pair a wind velocity of 50 km/hr is maintained; with the second 75 km/hr and 100 km/hr with the third. With this arrangement no variations in blower rpm are necessary to produce the desired velocities. The solar cell modules to be tested are mounted on weighted brackets in such a way that the entire outer face of each cell and the wire connectors are exposed to the dust storms. Before reassembling the race track an adequate amount of 'Martian dust' is distributed in the various sections. Prior to each test the atmosphere in the race track is swept out and replaced with CO₂ gas in which there is a trace of water vapor. The reason for the use of plexiglass in the race track is to make possible direct view of the dust storms. Preliminary tests have shown that some turbulence is generated in the curved sections, but that the flow in the straight sections when the tests are performed is essentially laminar.

Wind Tunnel No. 2.

The second tunnel is the same in design as No. 1, but except for the straight-away sections, is constructed of metal sheeting. The entire tunnel assemblage is covered with styrofoam sheeting. Provision is made for the introduction or removal of blocks of solid CO₂ from the metal portions of the "track" in order to control the temperature within the tunnel.

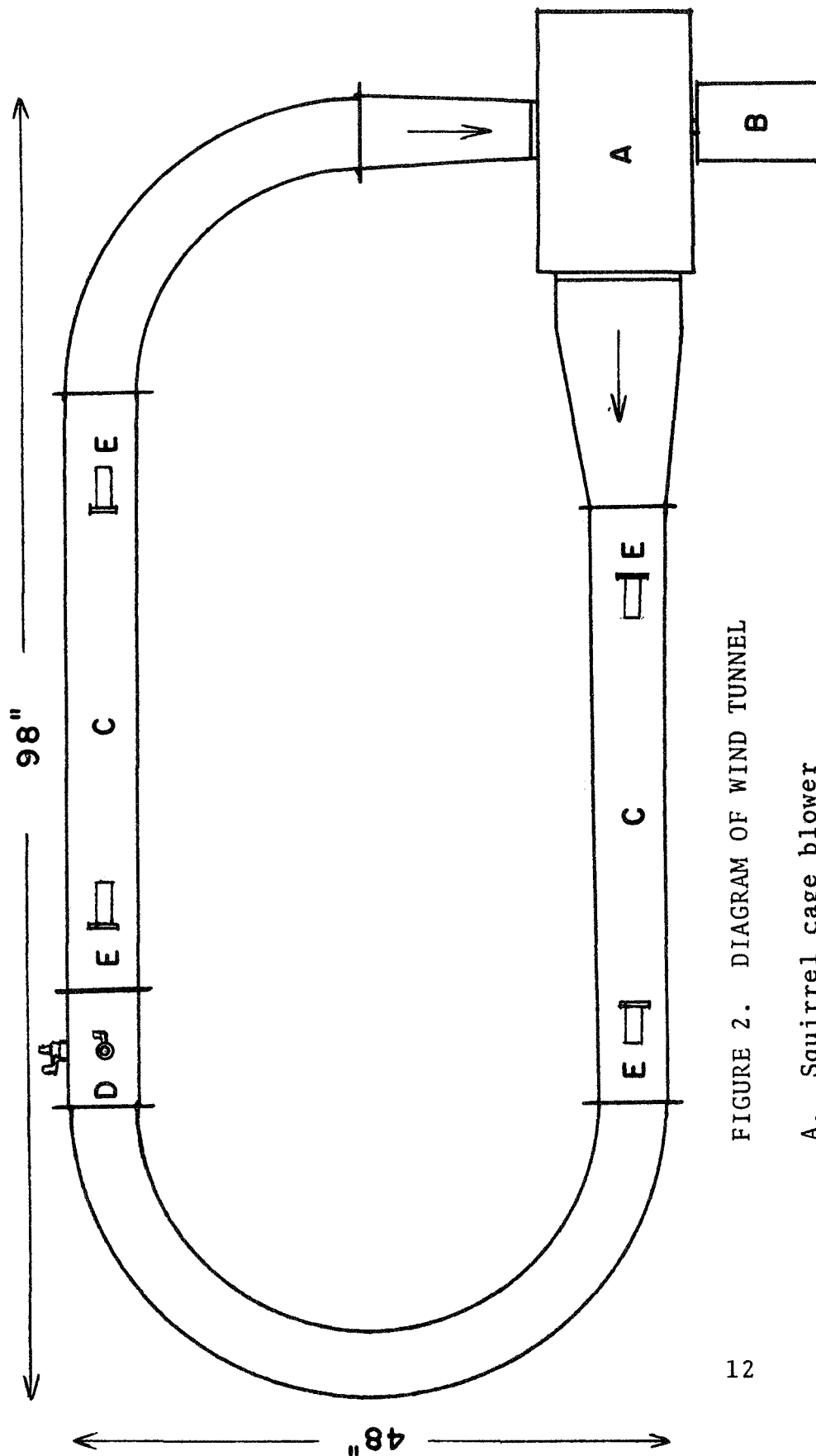


FIGURE 2. DIAGRAM OF WIND TUNNEL

- A. Squirrel cage blower
- B. Motor
- C. Removable straight-away sections
- D. Valve section. CO_2 inlet and outlet
- E. Solar cell assemblies